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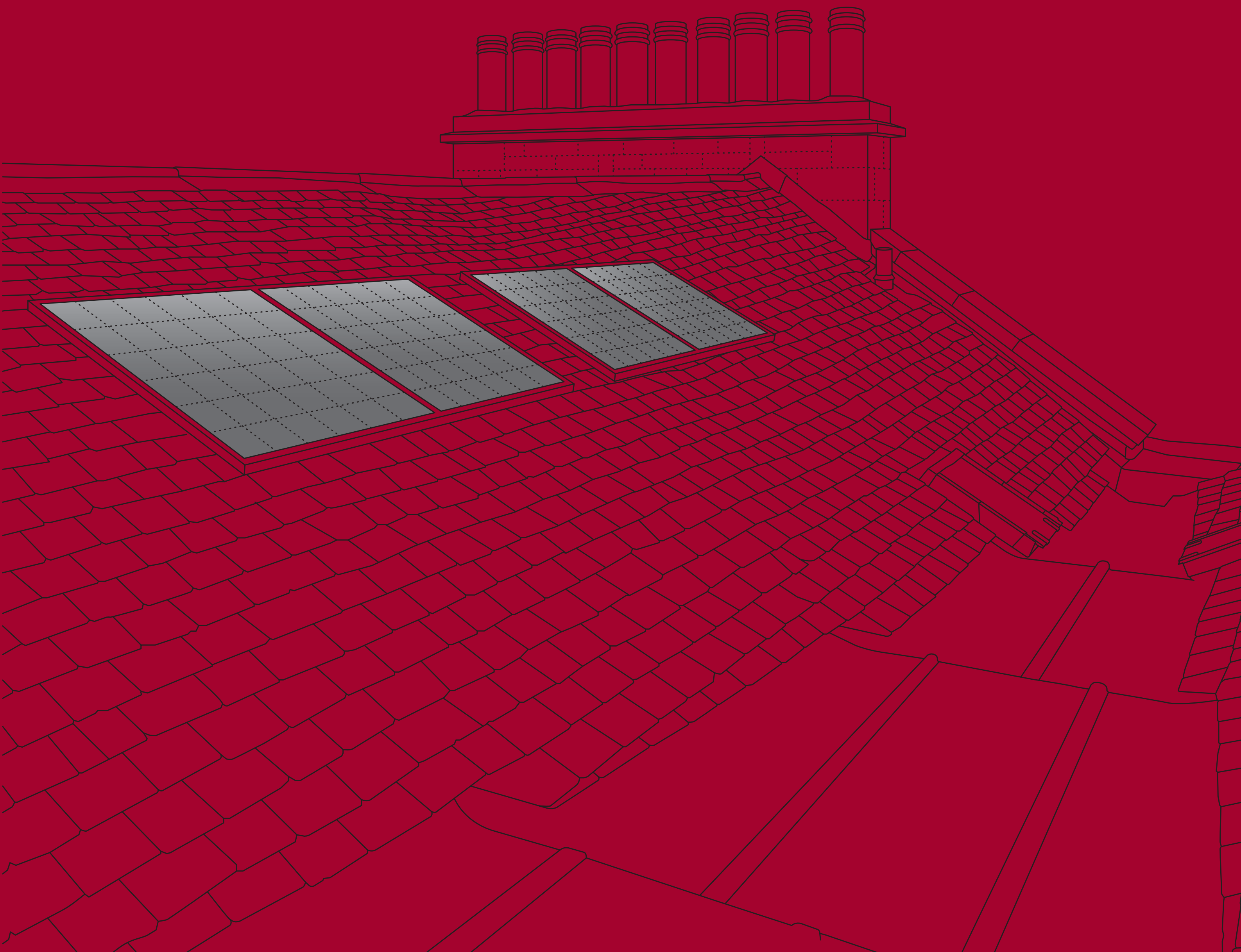
Short Guide

Micro-renewables in the Historic Environment



Historic Scotland
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National Conservation Centre
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HISTORIC SCOTLAND
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NATIONAL CONSERVATION CENTRE
IONAD GLÈIDHTEACHAIS NÀISEANTA

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Abbreviations

ASHP	Air Source Heat Pump
CHP	Combined Heat and Power
COP	Coefficient of Performance
EPC	Energy Performance Certificate
FiT	Feed-in Tariff
GSHP	Ground Source Heat Pump
MW	Megawatt
kW	Kilowatt (1,000 watts)
kWe	Kilowatt electric
kWh	Kilowatt hours
kWth	Kilowatt thermal
RHI	Renewable Heat Incentive
SEPA	Scottish Environment Protection Agency
SNH	Scottish Natural Heritage
Solar PV	Solar Photovoltaic

1. Introduction

This short guide discusses the use of micro-renewable technologies in the historic environment and highlights questions and considerations for when the installation of such systems is being contemplated. For the purpose of this short guide, 'renewables' are defined as energy sources which are considered replenishable (or infinite), as opposed to fossil fuels (oil, gas etc.) which are finite. 'Micro-renewables' are small-scale, non-commercial renewable energy systems which use zero or low-carbon technologies to provide space heating, hot water and/or electricity.

Renewable technology should be considered as part of a hierarchical approach to achieve a built environment that is energy efficient and conscious of the carbon and resources that it uses. The introduction of micro-renewables is not the first, nor the only way to make a building 'carbon conscious', especially one of traditional or historic construction. It makes little sense to invest in systems to produce renewable energy without first taking steps to reduce energy demand. An appropriate approach begins with proper building maintenance and efforts to achieve energy efficiency through behavioural change, building systems and fabric upgrades. This can range from ensuring that a building is wind and water-tight, to installing energy efficient lighting and heating systems, adding insulation or upgrading windows. There are numerous publications on historic building fabric upgrades, some of which are included in the further reading section at the back of this guide.

Having implemented the measures described above, installation of renewable energy systems should then be considered. In order for renewable technologies to be appropriate to a particular setting, not only should they make environmental and economic sense, reducing the amount of carbon and the cost of energy bills, but they should not alter or damage the character and significance of a historic site. The use of renewable energy technology is appropriate when the character of the historic building or place can be protected through careful siting and design of the system. Poorly planned, inappropriate installations of renewables may spoil the inherent character and aesthetic significance of a historic site. They may physically damage the building fabric and/or surrounding area (e.g. historic landscape or archaeological sites) causing irrevocable damage to our cultural heritage.

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Fig.1 Large-scale wind farm in background of St. Mary's Chapel, Crosskirk, west of Thurso (Scheduled Monument).

2. Background

To mitigate the effects of climate change and support a carbon conscious culture the Scottish Government has set world leading targets: to reduce Scotland's greenhouse gas emissions by 80 per cent by 2050 (from 1990 levels), with an interim target of 42 per cent by 2020. It is reported that the energy we use in buildings accounts for approximately 40 per cent of the UK's total carbon emissions (DECC, 2013), and renewable energy is recognised as an integral part of mitigating the effects of climate change. The Scottish Government's *2020 Routemap for Renewable Energy in Scotland* (2011) sets a number of supporting targets:

- 100 per cent of electricity demand equivalent from renewables by 2020;
- 11 per cent heat demand from renewables by 2020;
- At least 30 per cent of overall energy demand from renewables by 2020; and
- 500MW from community and locally-owned renewables by 2020.

In Scotland, traditional buildings (those constructed using traditional materials and methods, generally prior to 1919) number roughly 455,000 – approximately 19 per cent of building stock. There are also approximately 47,430 individually listed buildings, 8,071 scheduled ancient monuments, and 630 conservation areas. If carbon emissions from the built environment are to be reduced, energy use in traditional and historic buildings must also be addressed. Reducing the amount of energy we use in buildings and encouraging users to generate their own energy with micro-renewable technologies will allow the existing built environment to play its part in carbon reduction (Fig. 1).

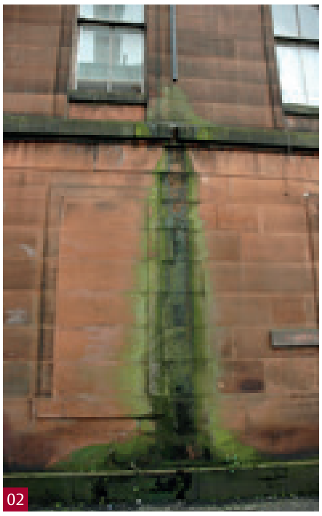
A 'micro-renewable' device, as legally defined by the Electricity Act 2004, is a system with a generation capacity no greater than 50 kilowatts for electricity (kWe) and 45 kilowatts for heat (kWth). Micro-generation includes a vast range of technologies, including biomass, solar power and combined heat and power (CHP). A number of these technologies are described in detail in section 5 of this guide. In some cases financial incentives from government are available for the installation and/or operation of certain systems.

3. The importance of energy efficiency in traditional buildings

The first steps towards reducing energy use are not difficult or expensive. Simple actions such as wearing appropriate clothing for the time of year and turning heating down by one degree can generate significant savings. It is also important to remember that no two buildings are the same in terms of their energy use, as this depends on a number of variables including the building fabric itself, the appliances used within the building and the behaviour and requirements of the occupants. Taking practical energy-saving measures as well as making fabric upgrades which retain a building's character and appearance will ensure that traditional buildings are comfortable and functional and continue to be of use to society for many years to come.

It is important to know your building and to understand how and where energy is used by conducting an energy audit. An energy audit reviews and documents the energy characteristics of a building to identify areas of energy waste and concludes with practical recommendations for improvement. Factors to consider include levels of insulation, heating controls, fabric materials and the use of the building. Organisations such as Energy Saving Trust, Resource Efficient Scotland, and Carbon Trust provide some useful guidance on conducting an energy audit, links for which can be found in the further reading section of this guide. Building owners/occupants should consider installing a smart meter to help determine exactly how much energy is being used at any given time, and review past energy bills. It is important to use radiator controls, boiler controls and thermostats. In many buildings heating controls and boiler settings are not understood or optimised for the occupants. A common sense approach is important; for example only heating rooms that are used, closing doors to prevent draughts and retain heat, only boiling the volume of water you need, installing low energy lights and fitting 'low-flow' showerheads, can all make a substantial difference to energy consumption. A certain level of energy efficient performance must be achieved if government subsidies for renewables are to be claimed.

Fig. 2 Damp masonry, and the associated soiling and biological growth, can be prevented with proper maintenance, which will improve thermal comfort.



Ensuring that a building is in good condition and has proper and regular maintenance is a prerequisite to undertaking any energy efficiency measures in any traditional building. The importance of controlling moisture ingress and ensuring vapour dissipation is paramount. If a building is not watertight there is little point in undertaking energy efficiency upgrades, and if dampness or excess moisture is already present such upgrades may cause further moisture accumulation and potential damage. Water penetration and consequent dampness in the fabric will increase heat loss and reduce thermal comfort, so it is important to ensure that gutters, downpipes, windows and other elements are in good condition (Fig. 2). A certain level of energy performance is necessary if any subsidies (feed-in tariffs etc.) are to be claimed, based on the Energy Performance Certificate (EPC) measurement achieved. Details of appropriate maintenance measures in traditional buildings are given in a number of Historic Scotland publications, noted at the end of this guide. Fabric upgrades to increase energy efficiency in traditional and historic buildings can

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Fig. 3 Keeping shutters closed is a simple, inexpensive way to retain heat in older properties.

be disruptive and invariably incur some costs, though are generally more economical than installing a micro-renewable system. Some fabric upgrades are more easily achieved than others. It pays to take simple actions first, such as using lined curtains, modified roller blinds and shutters to reduce draughts and increase thermal comfort (Fig. 3). When such existing elements are in need of repair, replacement or refurbishment, it can be cost-effective to reinstate or upgrade them.

Additionally, it makes sense to first improve parts of the building where there will be the least amount of disruption. This is likely to include insulating the roof space and/or applying secondary glazing to windows, or in certain cases insulating walls and floors. For example, most loft insulation can be easily applied and generally does not interfere with the building fabric (Fig. 4). Some fabric upgrades are best carried out if renovation of the building is already required or planned, for example applying insulation to a wall (Fig. 5) or laying an insulated floor.

Guidance on fabric improvements to traditional buildings to increase thermal comfort and energy efficiency are provided in Historic Scotland's technical research publications, including the *Short Guide 1: Fabric Improvements for Energy Efficiency in Traditional Buildings* (Historic Scotland, 2012) and the Refurbishment Case Study Series. A full list is included in the further reading section at the end of this guide. Only after fabric improvements have been undertaken and savings have been identified, should micro-renewables be considered.

Fig. 4 Sheep's wool insulation installed in a loft space.

Fig. 5 A blanket of aerogel insulation was applied to the internal face of the stone wall of this stairwell, and plastered over.

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4. Considerations for micro-renewables

The principal renewable energy sources currently suitable for micro-generation include heat pumps (air, ground and water), hydro, biomass, solar, and wind. There are a number of different technologies and types of equipment available for utilising each energy source. Sometimes two or more different energy sources and technologies can operate together to maximise renewable energy use such as using solar photovoltaic (Solar PV) panels to provide the energy needed to power a ground or air-source heat pump (Fig. 6). Domestic scale combined heat and power (micro-CHP) systems require separate fossil fuel sources, but can substantially improve conversion efficiency which is how efficiently a system can convert the input fuel to energy. Each micro-renewable technology has specific site requirements, and not all equipment is suitable for every site.

When selecting a micro-renewable technology, a range of factors should be considered to help determine what type of system or systems would be most technically appropriate and efficient for a site, as well as being appropriate for the nature of the historic site. The system should provide measurable carbon and cost savings, adding to those achieved from improvements in energy efficiency.

4.1 Statutory consents

4.1.1 Listed Building Consent

Listed Building Consent (LBC) must be obtained where proposals will alter the character of a listed building or structure. This applies regardless of the category of listing (A, B or C). It can include the installation of any new equipment where this will affect the character of the building or structure.

Fig. 6 Morgan Academy, Dundee (Category A-listed). Ground source and air source heat pumps are powered by solar PV panels located in the hidden valleys of the roof.

If the building is listed, the local planning authority should be contacted to ascertain if LBC is required before undertaking any work. To find out if a building or structure is listed the owner should contact the local planning authority or Historic Scotland.

The planning authority will determine whether or not work requires consent. All applications for consent are made through the planning authority and are decided by it. Any application should include accurate scale drawings showing the existing situation and proposed scheme with its associated equipment in context. It is always helpful to provide detailed technical information and photographs.

4.1.2 Scheduled Monument Consent

If a monument is scheduled, the prior written consent of Scottish Ministers is always required for works to that monument, including installation of new equipment. This is called Scheduled Monument Consent (SMC). The presumption is that all work should cause minimum disruption to the monument. If any proposed installations involve a scheduled monument Historic Scotland should be contacted at an early stage to discuss the proposal.

4.1.3 Planning permission

Planning permission may be required for alterations or installation of new equipment, for example installing new flues for a heating system or solar panels, particularly in conservation areas where permitted development rights (see section 4.1.4) are generally restricted. The planning authority will advise whether permission is required for works and what is likely to be granted permission.

4.1.4 Permitted development rights

In 2009 and 2010, the Scottish Government introduced a relaxation on planning controls, called "permitted development rights", on domestic properties for many of the more common types of micro-renewable technologies. This relaxed, and in some cases removed, the need for planning permission for many domestic micro-renewable systems. Specific details on what technologies this includes can be found in the Scottish Government's *Microgeneration Strategy for Scotland (2012)* and *Guidance on Householder Permitted Development Rights* (2012). The Scottish Government's Building Standards Division has also produced a series of guidance documents for the safe and sustainable installation of low-carbon equipment.

It is important to note, however, that permitted development rights do not extend to listed buildings and scheduled monuments, which are covered by other planning regulations. In such cases, listed building consent is required for most works to listed buildings and scheduled monument consent is required for all works to scheduled monuments per sections 4.1.1 and 4.1.2. Other restrictions apply to some types of micro-generation in Conservation Areas and World Heritage Sites. Further information on building and monument consents can be found in the further reading section at the end of this guide.

4.2 Establishing significance

It is important to have a clear understanding of the significance of the historic building or site and the various features or attributes pertaining to the building's character, such as original purpose, style, height, profile, materials and detailing, which contribute to its significance. These factors play a similar role in groups of historic buildings or streetscapes. While some buildings can be seen from all directions, other buildings may have obscured elevations that could be suitable for micro-renewable installations. The setting of a historic building is also important in establishing significance. Factors which contribute to setting in relation to 'historic assets' are outlined in Historic Scotland's *Managing Change in the Historic Environment – Setting* (Historic Scotland, 2010).

Establishing historic significance usually requires some degree of investigation and research, particularly if a building has not been listed or scheduled, or does not form part of a Conservation Area, World Heritage Site or an area of archaeological importance. Local authority planners may be able to offer some assistance with this. Alternatively, a conservation architect may be able to provide this service.

Knowing what makes a site significant will help assess the potential impacts and risks associated with the installation of a micro-renewable system, and influence its siting and other design factors in order to minimise negative impacts. Historic Scotland's *New Design in Historic Settings (2011)* offers useful guidance to practitioners. This publication deals primarily with the design of new buildings which sit within or alongside historic sites, but its general message is applicable to the integration of some forms of renewable technologies in a heritage context. It may be that the installation does not need to be hidden from view, but can become part of the on-going story and evolution of the building.

4.3 Energy needs

Knowing where energy is used, how much is used and how much is spent on it, should be the first steps taken when considering any micro-renewable system. It is also important to have an idea of the types of services an ideal system would provide, be it space heating, hot water, electricity, or all of these.

The 'heat load' of a building is the energy needed to raise and maintain the desired temperature of that building, and the 'heat loss' is the heat lost through the building fabric and ventilation. Calculating the 'heat load' and 'heat loss' determines the size of the heating system required and can help identify areas of poor insulation or increased air leakage (Shepherd, *et al*., 2012). Once this is understood, improvements can be made to increase energy efficiency and heating systems that are appropriately sized can be installed, saving money both on capital and operational cost. Oversizing of heating systems should be resisted, as unless a unit is working at full capacity, the efficiencies are not always realised. Correctly sized systems are less important for generating electricity as any shortage or excess may be imported/exported from the National Grid or be supplied by/stored in a battery. It is important to bear in mind that installation of a larger system will carry a higher capital cost, and that more than one type of micro-renewable system can be installed to meet different demands (Fig. 7).

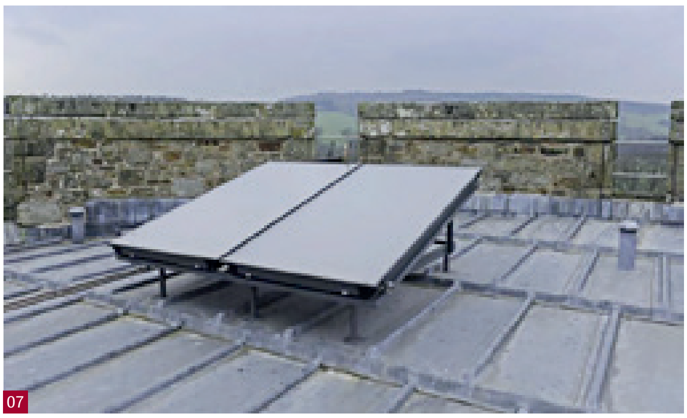
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Fig. 7 Discreet solar thermal panels provide hot water for Chirk Castle, Wales, (Grade I), during the summer. However, during the winter when there is a larger demand for hot water a biomass boiler is used. At some sites two biomass boilers will be installed, a larger boiler to provide heat and hot water during the winter, and a smaller one for the summer. This enables the boilers to be serviced when not in use and means that they are run at full capacity, at their most efficient (© National Trust).

As we burn fossil fuels, gases commonly referred to as 'greenhouse gases', are emitted into the atmosphere. There are a number of fuel sources, all of which vary in carbon intensity, i.e. the amount of carbon that is released into the atmosphere when we burn the fuel. Of the most common sources of fossil fuel-based energy, electricity has the highest carbon intensity, due to the high proportion of coal-fired power stations used for its generation. This is followed by coal, gas oil (e.g. 'red' diesel), burning oil (e.g. kerosene), Liquid Petroleum Gas (LPG) (e.g. propane), and natural gas.

A site's existing fuel source will, therefore, influence the carbon and cost savings of a renewable system. Renewables are most beneficial to sites that are not connected to national gas or electricity networks, or which rely on more expensive and high carbon fuel types such as propane or kerosene. This will result in faster paybacks and make significant contributions to carbon reduction.

4.4 Location and setting

Setting and location are important considerations and will greatly influence the type of renewable technology most appropriate for a site. The 'impact of change' on the historic environment must be considered (Historic Scotland, 2010), along with the suitability of renewable technology under consideration.

Micro-renewable wind turbines are most effective in rural locations where wind speeds average 6 metres per second (m/s). Ground source heat pumps may require a substantial area of land for coils to be entrenched 2 metres below the surface if laid horizontally, while solar thermal and solar photovoltaic panels should face south, be free of shade, and be mounted at a 30°- 50° angle.

In addition to location and setting, other existing conditions in a building may impact on the efficiency of various renewable types, such as existing mechanical systems and installations. For example, ground source heat pumps work particularly well with buildings that are heated using under-floor heating. Conversely, solar thermal panels should not be installed where a combination ('combi') gas boiler is used. Such systems heat water on demand, and do not make use of the heated water produced from the panels.

4.5 Cost and installation incentives

The initial capital cost of a system and its installation can be expensive, thus, cost is inevitably a significant factor when considering micro-renewables. Currently, grants and government-funded schemes, such as the Feed-in Tariff (FiT) and Renewable Heat Incentive (RHI), are available for electricity and heat-generating renewables. These help to reduce the payback time. A system should be as efficient as possible, otherwise it may not be cost-effective and could have a payback period that is longer than the life of the equipment. When considering any micro-renewable technology, a complete cost/benefit analysis should be carried out to determine financial viability.

To be eligible for RHI or FiT all micro-renewable technology equipment and installers must be certified under the Micro-generation Certification Scheme. More information about the scheme is available on the micro-generation website (see further reading at the end of this guide). In addition, to receive FiT at the standard rate, an Energy Performance Certificate (EPC) must be obtained for the building and must show that the property achieves an energy band of D or above. This is a further incentive to achieve energy efficiency in a building before taking steps to generate energy with renewable technologies.

4.6 Knowledge and optimisation of systems

It is imperative that potential users understand each micro-renewable technology so that the full benefits of the system may be achieved. Knowledge of a system's operation, how to monitor its performance and optimise its output is vital to the success of a project. It has been commonly reported that homeowners or users who have a poor understanding of the system do not experience the anticipated efficiencies or cost benefits. Installers and other authorities (e.g. landlords and housing associations) should provide information and guidance when a system is installed, although, conducting research and making enquiries for oneself is also likely to maximise the benefits to the user. Following installation, proper commissioning will be required.

4.7 Renewables on a community scale

Community energy schemes that allow a renewable energy system to be used by a number of buildings or a local community can be highly successful and cost-effective. District energy, as it is commonly known, makes use of a number of energy sources to provide heating, hot water, and occasionally electricity to many users. Common schemes include those using combined heat and power (CHP), biomass, energy from waste, heat pumps and hydropower, as well as fossil fuels. Fig. 8 and Fig. 9 show a district energy CHP in Falkirk.

In June 2013, the Scottish Government published its *District Heating Action Plan: Response to the Expert Commission on District Heating* (Scottish Government, 2013). This document sets out a number of key actions to help mainstream district energy systems and meet its target of 500MW of community and locally-owned renewable energy by 2020. It is important to research what is happening in an area prior to installing any form of micro-renewable technology. If district heating systems are being developed locally, this may present a more appropriate option, depending on the nature of the technology you are considering. The local authority should

Fig. 8 The district energy CHP in Falkirk produces 3,093MWh of electricity which is distributed to the National Grid and the re-captured heat is enough to heat six high-rise towers and Callendar House (Category A-listed).

Fig. 9 The CHP generator at Falkirk.

be able to advise of any current or future development plans of district heating systems, and whether or not this will affect you.

District energy can help communities achieve various environmental, economic and social objectives, providing efficient, affordable and low carbon energy to users. Some of the many benefits of district schemes include increased conversion efficiency through diversification of peak load times and economies of scale, and reduced susceptibility to future changes in energy availability and cost. Considering an energy scheme for the wider community, especially in urban areas, may open up new possibilities and streams of funding, such as grants and community share ownership. In addition, district energy may be less intrusive to historic buildings or sites as the amount of on-site equipment is typically less than that of a system for an individual site.

For further information visit the Community Energy Scotland website or the UK District Energy Association website.

4.8 Building evolution and change

Through the centuries, our built heritage has seen a number of changes, including the installation of sanitation, electricity, central heating and disabled access. These changes have been necessary to ensure the survival and longevity of our buildings. The use of micro-renewables is perhaps another stage in building evolution. If our historic environment fails to meet the ever increasing expectation for a cleaner and more energy efficient building stock, there is potential for such buildings to fall out of everyday use, if they are deemed too difficult to modify and too expensive to operate. There is, therefore, a very fine balance to be achieved between protecting the character and cultural significance of the historic environment and ensuring that it remains functional and can continue to contribute to society for future generations.

5. Types of micro-renewables

5.1 Space heating and hot water

5.1.1 Solar thermal

Solar thermal systems make use of the sun's energy to provide hot water and occasionally space heating. A pump circulates fluid through the solar collector (either a flat panel or a glass tube collector) which heats water in the cylinder via a heat exchanger. This hot water is then circulated through the building for heating or to provide domestic hot water. A back-up boiler system is also connected to the cylinder to provide hot water on days when the panels do not produce enough heat. Commonly, solar thermal systems simply help raise the temperature of the water inside the cylinder so that existing conventional boilers use less energy. To maximise the amount of sunlight the collectors receive, they should face south and be set at an angle of 30°- 50°C (Fig. 10). A typical system for domestic use requires around 3-4m² of collector, or around 1m² per person (CAT, 2012).

According to the findings of a survey completed by the Energy Saving Trust (Energy Saving Trust, 2011), a well installed and properly used solar thermal system can provide around half of a household's hot water needs and can produce around 1,500kWh of energy a year. Carbon savings ranged from 50 to 500kg per year. Hot water cylinders should be well insulated, and installing boiler timers or solar controllers will help ensure that water is heated by a back-up heat source only after it has been heated to the maximum extent by the solar thermal system.

A small amount of electricity is necessary to run the pump, which may be provided by solar photovoltaic (Solar PV) panels. There are also technologies available which combine solar thermal and photovoltaic technologies in one panel. However, these systems are expensive and, as advertised, may be better suited to new buildings.

5.1.2 Heat pumps

Heat pump systems provide space heating, cooling and hot water to a building by extracting heat from one medium and concentrating it in another. Heat at lower temperatures is collected from the air, ground or a body of water and is raised

Fig. 10 Solar thermal panels on the roof of a Category B-listed tenement within the Edinburgh World Heritage Site. Panels were appropriately set on the inside-south-facing pitch of an M-shaped roof, minimising their visibility from the ground and surrounding buildings.

using compression techniques to provide a more usable, constant source of heat for a building. Although electricity is needed to power the compressor in the pump, all heat pumps should generate more energy than they use, known as the coefficient of performance (COP). A pump with a COP of 3 means that for every kW of electricity used, 3kW of heat are produced; thus the greater the COP the more efficient the pump.

Heat pumps provide heat at constant temperatures (normally 40°C) over long periods of time, albeit at lower temperatures than conventional heating systems. Therefore, heat pumps are best suited to buildings that have good levels of insulation and retain heat (i.e. buildings must already be as energy efficient as possible). They are also best used with under-floor heating. Generally speaking heat pumps will only be more cost effective than a modern, efficient gas boiler if they achieve a COP of 4 or greater (CAT, 2012).

Principal considerations for the installation of heat pumps at historic sites include the need to avoid damage to potential underground archaeology and the need to find an unobtrusive location for the pump equipment and any surface pipework.

Air source heat pumps (ASHPs) take heat from the outside air (even at freezing temperatures) and raise it to an appropriate level for indoor heating (Fig. 11). The COP of ASHPs is more variable and can be severely reduced as temperatures drop, making the system less efficient or unusable, causing occupiers to rely on a traditional system for heat. Two types of ASHP exist; air-to-air systems, which transfer heat to an air distribution system and can thus only provide space heating, and air-to-water systems which provide heat to a water-based system and thus can provide both space and water heating to a building. In a domestic context air-to-air systems are sometimes difficult to install in existing buildings because the system requires ductwork.

Ground source heat pumps (GSHPs) require long lengths or coils of special-grade pipe to be laid in either a horizontal trench or vertical borehole. Horizontal systems generally require an area of 10 linear metres per kW for coils to be entrenched at a depth of 2 metres, and vertical systems require boreholes (which may require special permissions from the Scottish Environment Protection Agency) of around 100-150 metres deep and 20-50 metres of pipe per kW (Fig. 12).

Fig. 11 Air Source Heat Pump, Llanerchaeron, Wales.

Fig. 12 Installation of a Ground Source Heat Pump (GSHP) at Assynt Church, Inchnadamph (Category B-listed). The coils for the system were installed in trenches behind the church (© LDN Architects).

Fig. 13 Passive solar energy system which collects heated air from below the slate roof (© Richard Atkins, Chartered Architect).

As installation is more complicated, GSHPs are more expensive and disruptive than ASHPs; however, they do tend to achieve higher COP as the ground remains at a more constant temperature all year round. Cost will vary depending on a vertical or horizontal system (vertical boreholes will be more expensive). Coils can also be laid in the beds of watercourses.

Water source heat pumps are less common but can be as efficient as ground source heat pumps, providing the water source does not freeze. In some cases historic millponds may be suitable locations for water source heat pumps.

More recent developments in heat pump and heat recovery technology include internal roof-space heat exchangers that utilise heat created from the solar gain of existing roof coverings or exhaust air from internal areas such as kitchens or bathrooms. A refurbished Category B-listed school building at Norton Park, Edinburgh, built in 1902 and converted to office space in 1999, successfully installed an air handling unit with heat exchangers that collects heated air from below the existing slate roof covering (Fig. 13). This passive solar strategy did not require any alterations that negatively impacted on the historic fabric and is energy saving. It contributes 6°C of 'free' heat to the ventilation air during the heating season, (BRE, 2001 and Atkins, 2011).

5.1.3 Biomass

A wide variety of organic material (wood, crops, agriculture/municipal/industrial waste) can be burned in biomass systems to provide heat and hot water. Small-scale biomass developments are predominantly based on wood fuel products including logs, wood chips and pellets (compressed sawdust). These products are considered a renewable resource as they are, in effect, carbon neutral. Trees absorb (sequester) carbon while they live and grow, before releasing it when burned. Since trees can be re-planted and forests replenished, it is acknowledged that the carbon released in combustion will be absorbed again over time.

In addition to the wood burning equipment (boilers or wood burning stoves), systems require fuel storage, pipework and chimneys/flues. Accumulator tanks (heat storage tanks), improve the efficiency of biomass boiler systems as they


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Fig. 14 Insulated accumulator tank for the biomass boiler system at Rosslyn Chapel (Category A-listed).

Fig. 15 Rosslyn Chapel biomass facilities and fuel store (for pellets) are underground and sited at the far end of the car park.

store heat produced in water until it can be used (Fig. 14). A dry storage space for the biomass fuel is essential, especially for logs and wood chips as they need to be well seasoned to achieve a low moisture content to be burned efficiently. The boiler system, as well as the location and design of the boiler house, and variables concerning the fuel such as type, storage facilities, delivery schedule and distance the fuel travels to the site, will vary and may affect efficiency, carbon reduction, payback and return on investment (Fig. 15). Delivery access also needs to be considered, as narrow, historic streetscapes may be unsuitable for large goods vehicles.

The boiler equipment and installation cost is substantially more expensive than that for conventional boilers, although biomass fuel is less costly than oil, LPG, electricity and natural gas, such that it should prove more economic over time. Cost will again vary on the size and type of system installed. The amount of wood fuel a three or four bedroom detached house is expected to consume ranges from 4.4 to 6.6 tonnes per year, equivalent to 0.4 to 0.7 hectares of woodland. Different types of biomass fuel have different calorific values (the amount of energy stored in each kg of fuel). For example, wood pellets have higher values than wood chips or logs, though this is dependent on the moisture content. Increased calorific value will affect the efficiency and quantity of wood fuel needed, thus influencing storage facilities and delivery schedules (Shepherd *et al*., 2012) (Fig. 16).

The general principles of careful siting and design apply to this type of development. Particular care must be given to the location of chimneys/flues and the fuel storage facility, given that large volumes of fuel may need to be stored and regular deliveries made. Historic Scotland's *Refurbishment Case Study 12 – Kincardine Castle* (2014) documents the installation of a biomass heating system serving a large domestic property. It provides information on the site work involved, financial implications and the energy savings achieved.


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Fig. 16 Fuel store for a biomass boiler serving Kincardine Castle, Aberdeenshire. This small storage facility is refilled from a larger shed located further away. This storage shed has been built behind a timber dog kennel, and is hardly visible from the castle.

5.2 Generation of electricity

5.2.1 Solar photovoltaic (Solar PV)

Solar PV produces electricity when light reaches the semiconductor material and energises the electrons in the solar module, creating a direct current (DC) of electricity. This is then converted to an alternating current (AC) by an inverter to be used in a building's electrical system. It may also be exported to the National Grid or stored in a battery for later use. Many factors can affect the output of a solar PV system including the type of module used, the size of the array (linked collection of solar panels), the orientation of the array to the sun and shading on the modules. The conversion efficiency of a system is determined by the amount of light energy that can be captured and turned into electrical energy. Technologies that increase the amount of light entering a solar cell and enhance the ability of the cell to trap different frequencies of light are more efficient.

Types of modules include amorphous, crystalline, and hybrid systems. Amorphous cells are made of thin, flexible, non-crystalline silicon film, which can be attached to a variety of materials and tend to be less susceptible to shading and low light levels, though are the least efficient type. Crystalline cells are made of silicon crystals and have conversion efficiencies of 8 to 15 per cent. Hybrid systems, which use both crystalline and amorphous technologies are the most efficient (around 20 per cent) and more expensive (Plug into the Sun, 2009).

Solar modules are available in many forms such as tiles, films and cells, which can be integrated in the roof or glazing of a building (Fig. 17), but they are most commonly found as panels, which can be mounted on roofs (Fig. 18 and Fig. 19) or on separate frames on the ground, for example in gardens (Fig. 20), connected to a building by cable.

The ideal siting for solar collectors (in Scotland) is a south-facing, unshaded aspect set at an angle between 30° and 50°. The amount of electricity that is produced depends on the amount of light that falls on the collectors. On cloudy days, panels will typically produce a third of the amount of electricity they would produce on a sunny

Fig. 17 Solar cells, Centre for Alternative Technology, Wales. Photo taken from underside of roof.

Fig. 18 Solar panels integrated into the roof, Centre for Alternative Technology, Wales.

Fig. 19 Solar panels mounted to a frame on the south-facing pitch of an ancillary building.

Fig. 20 Solar panels mounted on a retaining wall in the garden.


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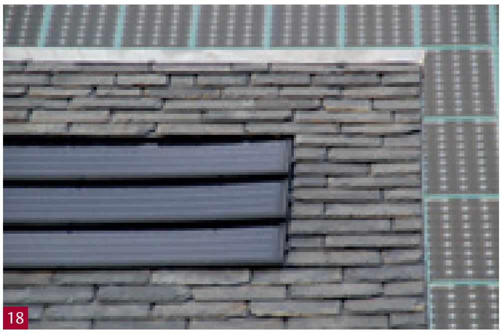
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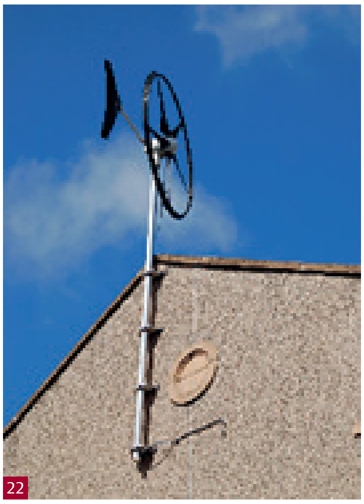

day. Obstructions causing shade severely reduce efficiency. If a shadow is cast over even a fraction of a solar module, the entire array will be affected and electricity generation will be substantially reduced, potentially to zero (Plug into the Sun, 2009).

To help building owners calculate the potential energy generation through solar panels, the Energy Saving Trust has created a solar energy calculator (see further reading section) to estimate how much a PV system will generate in a specific location. A 3.5kW system can produce around 3,000kWh per year (CAT, 2012). While Feed-in Tariffs do help recover the capital cost of solar panels, the rates are lower than they were when the scheme began, and they are likely to continue to decrease over time.

5.2.2 Wind power

Wind turbines are perhaps one of the most well known and visible forms of renewable energy in the UK. Electricity is produced when wind turns the rotor blades, which drives a turbine to generate electricity. Micro-wind turbines are most efficient when freestanding and placed in exposed locations, where there is little obstruction from trees and buildings and they can be positioned at a height and angle where wind speeds are the greatest (Fig. 21). Whilst in practice they can be mounted to buildings, typically on flat roofs or attached to gable ends, this is not recommended. This is not only due to the structural loading on the building, but because they are unlikely to perform well, as such locations tend to receive weaker and irregular winds (Fig. 22).

All wind turbines are designed with a 'cut-in' wind speed and a 'rated' wind speed; that is, respectively, the minimum wind speed, in metres per second (m/s), necessary for a turbine to produce energy and the wind speed necessary for a turbine to produce the amount of energy at which a turbine has been rated. Cut-in wind speeds range from 2.5m/s to 5m/s and average rated wind speeds are 11m/s to 12.5m/s. In order for wind turbines to be efficient and cost effective, the Energy Saving Trust (Energy Saving Trust, 2009) recommends that turbines should not be installed unless the average wind speed of the site is 6m/s.

It is important, as with all renewables, that the technology is suitable for the conditions at the site and that the installer is certified under the Microgeneration Certification Scheme so that Feed-in Tariffs can be claimed to maximise the economic benefits.

Fig. 21 Westray Parish Church, Orkney (Category C-listed). The 6kW turbine is far from the building, thus in an exposed position and reducing the visual intrusion to the setting.

Fig. 22 Wind turbine mounted to a gable end of a building in Edinburgh. In such situations the limitations of the site, expense of the turbine and its maintenance often outweighs the benefits.

5.2.3 Hydropower

One of the oldest and most simple forms of renewable energy, hydroelectric schemes have been used since the 19th century. Hydropower systems use the kinetic energy of flowing water to drive a turbine and associated generator. The electricity produced can be used onsite or exported to the National Grid. In most systems an intake diverts water from a river or stream through a pipeline to a turbine house. Here, the water passes through a turbine, which drives a generator to produce electricity (Fig. 23 and Fig. 24). In other systems a dam or weir may be used to store water so that its use can be controlled.

The amount of electrical power produced depends on the 'flow' and 'head' of the water source; that is, the velocity and volume of water used to turn the turbine and the height, or vertical distance, from where the water is taken to where it passes over the turbine. There are many different types of turbines that may be used depending on the head and flow characteristics of the site. For example, an Archimedes' screw turbine type is commonly used on low-head sites (5-25 metres) (CAT, 2012).

In order to determine the suitability of a hydro scheme it is important that a landowner conducts research and consults appropriate professionals such as engineers, hydrologists, financial advisors and certified installers. Once it is felt that a hydro scheme will be successful the local planning authority and environmental organisations, such as Scottish Natural Heritage (SNH) and Scottish Environment Protection Agency (SEPA), will need to be consulted and planning applications submitted. Certain environmental requirements, such as detailed environmental statements or approved fish passages, will differ depending on the size and site of the proposed scheme. In all cases, an abstraction licence is needed to intake water and return it to its source.

While expensive, site specific and planning intensive, hydropower systems can be very successful, robust, and long-lasting schemes. Generally, the cost per kW of a hydro scheme decreases as the size of the system increases. There has been increasing interest in the potential for the reuse of old mill sites and historic hydro schemes that have long been unused and forgotten.

Fig. 23 Balbeg Hydro, Ayrshire. A 27kW hydro scheme takes water from the Balbeg Burn and passes it through 500m of pipe to the turbine house (© Energy Saving Trust).

Fig. 24 Electricity being generated at the turbine house at Balbeg Country Holidays' self-catering cottages, Ayrshire. Excess is exported to the National Grid (© Energy Saving Trust).


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Where possible, the recording, repair and reuse of historic weirs, mill lades, turbines and waterwheels is encouraged (Fig. 25). Further information on hydro schemes can be found at the end of this guide.

5.2.4 Combined heat and power

Combined heat and power (CHP) is a dual energy system that harnesses heat from the generation of electricity, which is typically produced by a gas generator. While not a renewable energy system *per se*, as it still uses fossil fuel sources (though may be fitted to run using renewable fuels such as biomass), it can be a viable option for replacing standard boiler systems. This is because the electricity generation by CHP is far more efficient than that produced by a conventional power station, where a large amount of energy is lost in delivery to the consumer through the distribution network. For maximum efficiency, CHP is best suited to meet constant heat demands, and systems should be sized to meet the base-heating load in order to maximise running hours. A study by the Carbon Trust (2011) recommends that micro-CHP systems best serve detached houses with four or more bedrooms or small-scale commercial applications.

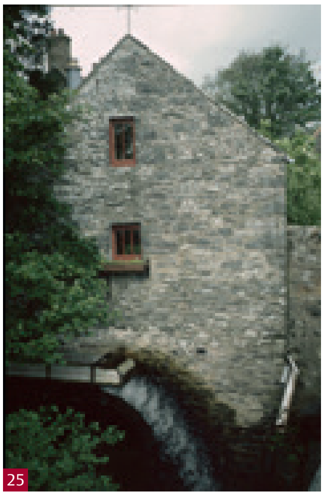

Fig. 25 A former corn mill in the Scottish Borders where a waterwheel was re-introduced to power a pump for a ground source heat system. The historic mill pond, weir (caul), lade and wooden launder (trough) were all reused to drive the new wheel.

CHP is eligible for the FiT and, though initially more expensive than a condensing boiler, if appropriate for a building, the savings made from generating electricity and receiving the FiT can result in an anticipated payback period of around ten to twelve years. The heat output from some forms of CHP in non-domestic buildings makes them eligible to receive support from the RHI, specifically those using geothermal, biogas, solid biomass contained in municipal waste or solid biomass sources of energy. However, there are a number of intricacies relating to the eligibility of CHP under the RHI; great care should be taken in using this as a decision factor. More information on the eligibility of CHP under the RHI can be found on Ofgem's website (see further reading section).

In addition to micro-CHP schemes, there are district energy schemes that make use of CHP technology, successfully connecting and distributing heat from a central CHP station to customers in buildings spread across a populated area. CHP is an efficient technology for generating electricity, providing heat and reducing carbon footprint. On a district scale CHP offers improved efficiency through load diversification and economies of scale. For example, in Falkirk, a district CHP scheme provides heat for six high-rise towers and the historic Category A-listed Callendar House. In 2012-13 a 1MW generator produced 3,093MWh of electricity which was exported to the National Grid, and 5,280MWh of heat was supplied to over 300 domestic properties (Fig. 26) and Callendar House (Fig. 27) (Falkirk Council, 2014). District energy schemes may be feasible where a community or several parties are interested and dedicated to pursue such works, and can be appropriate for traditional or new buildings – domestic, public and commercial.

Fig. 26 Heat from CHP supplies six high-rise towers, Falkirk.

Fig. 27 Heat from the same CHP supplies the A-listed Callendar House, Falkirk.

6. Minimising impact

Renewable energy systems, no matter their size, will have some impact on the building or site they are serving. However, ensuring that the system is integrated and installed in a way that minimises impact can help affirm the system's validity and appropriateness. There must be a balance between maintaining the historic integrity of the building and ensuring its usefulness in the future. As discussed in section 4 a building's significance and character should first be considered, and any potential visual and physical effects which may negatively impact on this should be carefully addressed. Issues such as reversibility – the sensitive removal of a renewable system at the end of its life – and ensuring that a building's authenticity, historic fabric, and defining features are retained for future generations, are also important. If no appropriate alternatives or ways exist to sensitively address such aspects then it may be in the best interest of the building or site to forgo installation and seek alternative ways of achieving carbon reduction, for example, by making improvements to the building fabric or installing highly efficient conventional systems.

6.1 Visual impacts

Many historic buildings or places are suited to the implementation of some form of micro-renewable energy generation. Installation must be planned carefully to ensure that the historic character of each site is maintained, and to make best use of the available renewable energy sources. To minimise the visual impacts that may occur, careful consideration must be given to choosing a suitable location for the renewable system and all associated equipment. There is sometimes a balance to be struck between which location is best in terms of sensitivity to the site's visual appearance and which may be best for energy generation.

Solar collectors located on secondary roof slopes or on surrounding areas such as sheds, gardens, or fields are generally preferable. Successful installations have placed panels behind parapet walls or on the inside-south-facing slope of M-shaped roofs (Fig. 28). Solar PV technology is such that collectors are also available as tiles, which can mimic slate and be integrated into the roof (Fig. 29). While this may be more visually sensitive, such an installation should only be considered where a roof is in need of replacement, where historic building fabric will not be inappropriately altered. The life span and reversibility of such systems should be considered.

Fig. 28 The solar panels on the inside face of this M-shaped roof are hardly visible from the ground.

Fig. 29 Solar tiles at Morden Hall Park, London, attempt to mimic the appearance of slates.


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Fig. 30 Solar panels initially installed on one cottage affect this entire streetscape in East Lothian as the installation has encouraged other residents to make similar installations.

Commonly, renewables may have a visual impact beyond that of a single building or site, and entire streetscapes or landscapes may be affected (Fig. 30). Planning permission can be denied on the basis that an installation will affect the overall character of a streetscape or will set an inappropriate precedent, increasing the likelihood of similar installations across a neighbourhood, often referred to as the 'domino effect'.

Wind turbines should be sited away from historic structures and be as sensitive to the surrounding landscape as possible. Hydropower systems should also be as visually harmonious and as least disruptive to the natural landscape as possible.

Renewable systems requiring space for larger equipment, such as biomass boilers, should not only consider appropriate siting for such facilities but also their design, size, form, material, colour and texture. Effort should be made to complete a design that can be well integrated with the aesthetic of its surroundings, built and natural. Depending on the site, boilers, tanks, pumps and fuel storage may be integrated into existing buildings or placed in purpose-built structures. (Fig. 31 and Fig. 32). The design and ability to access such structures is important for providing systems that are both appropriate to the site and easy to operate, maintain and repair.

Fig. 31 Scotstoun House, South Queensferry. The purpose-built structure to house the biomass boiler has been integrated into the existing entrance arch and has little visual impact on the site.

Fig. 32 A double dog kennel was constructed in front of the biomass boiler house at Kincardine Castle (Category B-listed). The boiler house, to the rear, is also built into the hill-side. Photo taken from the roof of the Castle (© Andrew Bradford, Kincardine Castle and Estate).

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6.2 Physical impacts

Physical impacts include those affecting structural, archaeological and environmental aspects of the site as well as issues concerning access to the systems for fuel delivery (biomass), repair and maintenance. During installation, it may be necessary to alter or remove historic fabric, which can include the attachment of frames or fixtures to the roofs, the need for pipes and wires to pass through the building interiors and the integration of pumps, boilers, and storage tanks with existing conventional systems. The building or site may also be affected during the system's use and operation. Issues such as vibrations, emissions and noise, to name a few, have the potential to disturb or impact on the building or site as well as potential archaeological and natural resources.

Systems installed on roofs or gables of buildings (solar collectors or small wind turbines) can be heavy and an appropriate survey should be carried out to determine structural impact and safety. Care should be taken to minimise damage to the historic fabric through installation and fixings, and the potential for reversibility should be considered (i.e. the removal of the system at the end of its life). Solar collectors may be installed on frames set onto pitched or flat roofs, or may be integrated into the roof so that they are flush with the roof covering. The latter should be done only if the roof is in need of replacement or repair, as it is otherwise unnecessarily intrusive and expensive to remove original roofing fabric (Fig. 33). Similarly, under-floor heating, while optimal for heat pumps, may be difficult to install without significantly disturbing the building fabric. Installations that require fixing to historic masonry should be done with minimal disturbance (e.g. placing fixings in existing mortar joints where mortar can easily be replaced).

Installation of ground equipment, predominantly for ground source heat pumps, underground distribution pipes, cables for freestanding solar collectors, pylons for wind turbines and underground wood fuel storage facilities, may disturb historic or archaeological evidence. Where such sites are known to exist or are likely, it

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Fig. 33 Solar PV tiles designed to look like slate are integrated into a slate roof during refurbishment works (© Solar Slate www.solarslate-ltd.com).

Fig. 34 Installation of Ground Source Heat Pump (GSHP) at Castle Howard. An archaeologist supervised all necessary ground disturbance during the work, during which a revetment wall was uncovered (© Hon. Sir Simon Howard/Castle Howard Estate Ltd).

may be inappropriate to continue with installation, though it may be possible to proceed with an archaeological watching brief to monitor installations requiring ground disturbance (Fig. 34).

Physical impacts related to biomass boilers typically concern fuel storage and delivery. Boilers are commonly placed in secondary buildings or purpose-built structures. However, separate sheds are typically needed to store the wood fuel and some sites may invest in underground silos for storage (Fig. 35). Commonly, large spaces are created in order to hold more fuel, therefore reducing deliveries. Depending on the delivery method, accessibility to the storage facility may also affect the site and should be carefully considered.

Renewables may also have an effect on wildlife and the natural environment. Appropriate advice should be sought from Scottish Natural Heritage (SNH) and the Scottish Environment Protection Agency (SEPA), especially for installations affecting designated natural heritage sites and protected species.

Fig. 35 Biomass fuel storage silo, Rosslyn Chapel. The large underground pellet silo allows for easy deliveries from the supplier.

7. Summary

There are many factors to consider when deciding if a renewable energy system is a suitable option for a historic building or site. The nature of each renewable technology requires that additional considerations be made so that the chosen system can be as efficient and as appropriately sited as possible. Taking practical energy saving measures and making fabric improvements before micro-renewable installations are considered will ensure that the most cost-effective steps are taken to reduce energy and lower the carbon footprint.

Renewables should make environmental and economic sense, and should not irrevocably alter or damage the character and significance of a historic site. Thus, the main questions which should be asked are whether the renewable energy system will make significant carbon and cost savings as to warrant any impact which may occur, and whether the visual and physical impacts can be successfully minimised so that the significance and character of the site remains intact.

Many historic buildings can successfully incorporate micro-renewable technologies, but their installation must be planned carefully because, when poorly thought out, inappropriate installations of renewables may damage the inherent character of the site and may not make cost-effective energy and carbon savings.

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www.historic-scotland.gov.uk:

Historic Scotland (2010), *Managing Change in the Historic Environment – Setting*,
http://www.historic-scotland.gov.uk/managingchange

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Historic Scotland (2013), *Guide to the Protection of Scotland's Listed Buildings*
http://www.historic-scotland.gov.uk/scotlandslistedbuildings.pdf

Additional technical publications are available from Historic Scotland's Technical Conservation website www.historic-scotland.gov.uk/conservation:

INFORM: Energy Efficiency in Traditional Homes (2011)

Maintaining Your Home: A Short Guide for Homeowners (2007)

Refurbishment Case Study 12 Kincardine Castle: Installation of Biomass System (2014)

Short Guide: Fabric Improvements for Energy Efficiency in Traditional Buildings (2012)

The Energy House (computer-based interactive tool, 2012)

Websites

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Carbon Trust: Tools, Guides and Reports	www.carbontrust.com/resources
Centre for Alternative Technology	www.cat.org.uk
Community Energy Scotland	www.communityenergyscotland.org.uk/support
Energy Saving Trust	www.energysavingtrust.org.uk/scotland
Energy Saving Trust Calculator	www.energysavingtrust.org.uk/Generating-energy/Getting-money-back/Solar-Energy-Calculator
English Heritage Climate Change & Your Home	www.climatechangeandyourhome.org.uk/live
Falkirk Council	www.falkirk.gov.uk
Historic Scotland	www.historic-scotland.gov.uk
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Micro-Hydro Association	www.microhydroassociation.org
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